7.4: A 6 KW PEAK POWER VARACTOR DUPLEXER

JOHN C. HOOVER

Sperry Microwave Electronics Co., Clearwater, Florida

The varactor diode, due to its voltage dependent capacity, exhibits a nonlinearity in impedance with changes in RF power level. This change in impedance is sufficient to provide switching action. In addition to this switching action, the varactor junction has an erg burn out level on the order of a thousand times that of a mixer diode. Because of these two properties, the varactor is very applicable in solid state duplexers and limiters for mixer diode protection.

The performance of the solid state duplexers depends on the degree of change in the impedance level of the varactor. This impedance change can approach the square of the change in Q of the varactor junction. If the varactor is driven into conduction in the high power state, the change in Q will be the operating Q of the varactor; this Q being the ratio of junction capacitive reactance to the diode series resistance, or equivalently, the ratio of cutoff frequency to operating frequency. At 1 Gc/s a feasible Q is 40. Thus, the dynamic range in impedance would approach 1600. Because of the Q^2 relationship the dynamic range would fall off at higher frequencies by a factor of the frequency squared.

This limits the development of varactor duplexers using presently available varactors to frequencies up to about 2 Gc/s. In spike clipping applications, where the varactor can safely dissipate the total spike energy, practical devices can be built at frequencies into X band.

An L-band semiconductor duplexer was successfully developed and tested for an altimeter radar for a missile application. Operation was at 6 kw peak, 6 watts average transmitter power at 1600 Mc/s. The theoretical power handling capability was 24 kw peak. Actual measured insertion losses were 0.3 db from transmitter to antenna and 0.6 db from antenna to receiver. The transmitter to receiver isolation was greater than 40 db over a bandwidth of 100 Mc/s.

The internal structure and equivalent circuits of this device are shown in Figure 1. Figure 2 is a photograph of the device.

Referring to Figure 1, the varactors at B and E are inductive on the transmit cycle. This inductance is tuned out by the parallel capacitance thus producing a high impedance. This is reflected at C as a low impedance and at D as a high impedance; thus the transmitted energy goes out the antenna arm. The second stub (E-F) is used to produce more isolation between the transmitter and receiver. On the receiver cycle the varactors are capacitive thus reflecting an inductance at F and C. This inductance is tuned out by the capacitance shown, producing a high impedance. The impedance of the transmitter is high; therefore, the antenna looks into the relative matched impedance of the receiver. The equivalent circuits at

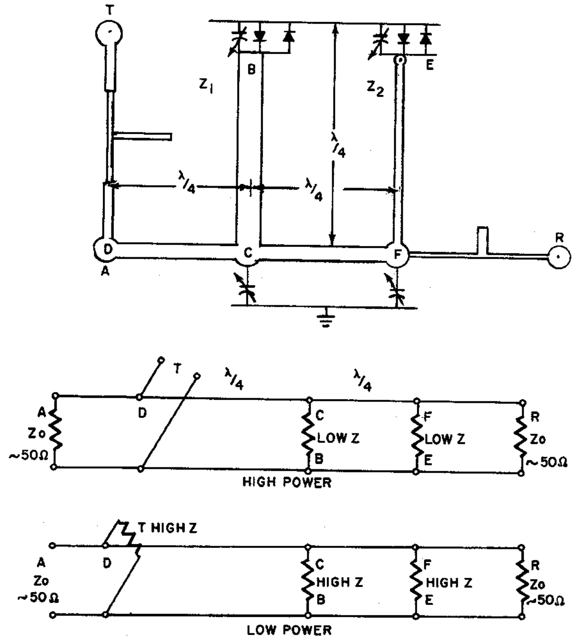

Fig. 1. Structure and equivalent circuits of diode duplexer.

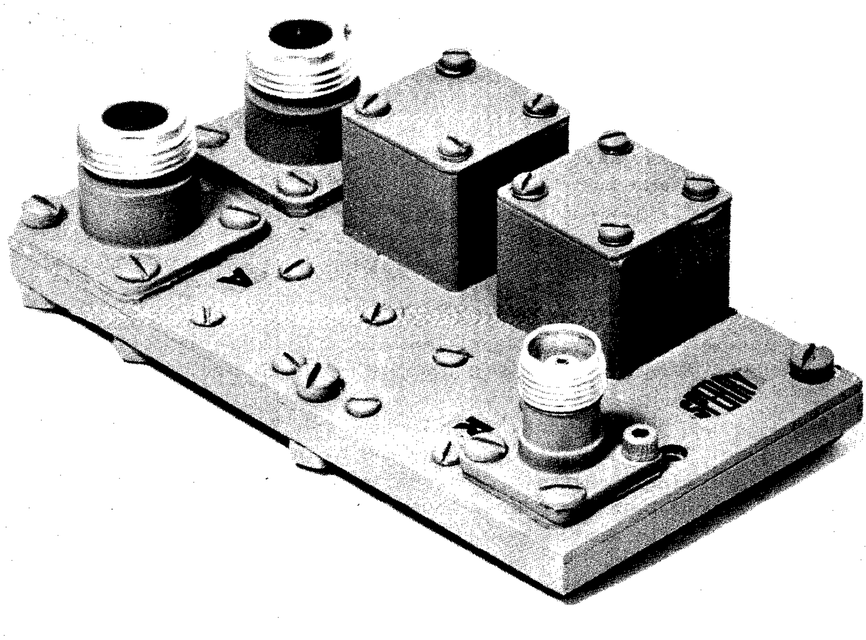

Fig. 2. High power varactor duplexer at 1600 Mc/s.

low power and at high power of this device are shown in Figure 1. The impedance of the stubs are used to control the distribution of insertion loss between the transmit and receive cycles.

The stub nearest the transmitter has a low impedance giving a low insertion loss for the stage during the transmit cycle. This results in higher power handling capability than would be obtained with a stub of higher impedance. As the second stage has the benefits of the limiting of the first stage during the transmit cycle, it can be optimized for low insertion loss during the receive cycle. This is done by making the stub impedance high.

A duplexer can be designed using a balanced type structure with two short slot hybrids or two 3 db couplers as shown in Figure 3. In this structure the varactors are at points marked "V" and serve to short out

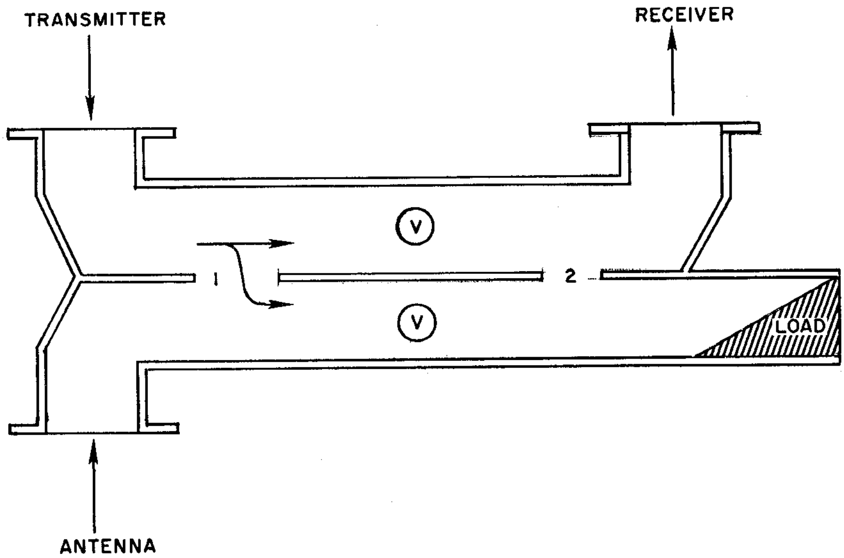

Fig. 3. Structure of balanced line semiconductor duplexer.

the lines under the transmit cycle but pass the signal under receiving conditions. The structure has the advantage of increasing the receiver protection by the amount of the isolation provided by the hybrids but has one quarter the power handling ability of the previously described structure for the same low power insertion loss and varactor Q. The reason for the four-to-one difference in power handling ability can be visualized from Figures 4 and 5. Figure 4 is representative of the standing waves existing under the high power state on one line of the balanced duplexer while Figure 5 is representative of the standing waves of the branched type structure. It can be noted that the terminated branch line of the branch line duplexer reduces the RF current through the varactor by a factor of two, thus reducing the I^2R loss by a factor of four.

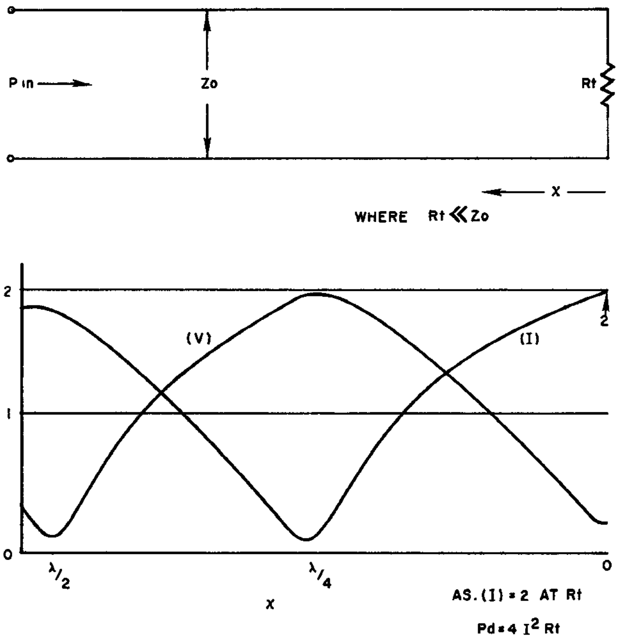

Fig. 4. Current distribution on a short circuited stub.

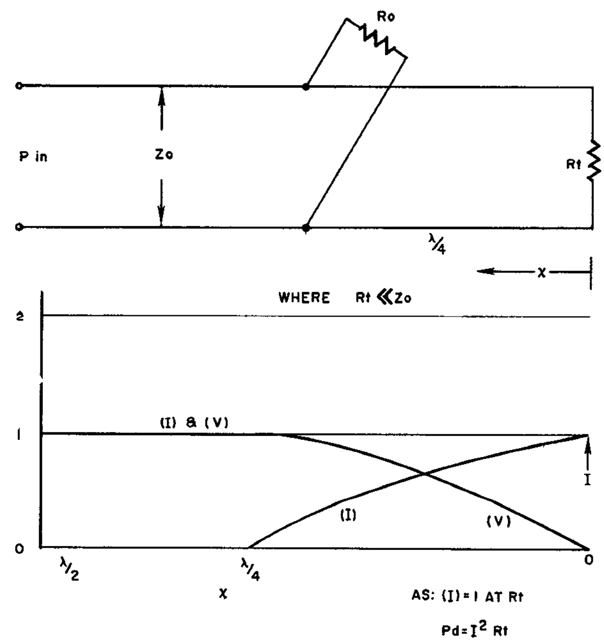

Fig. 5. Current distribution on a ported short circuited stub.

Varactor solid state duplexers differ from TR or ferrite duplexers in that there is essentially no spike leakage and that the two-way insertion loss of the duplexer is dependent on the Q^2 of the varactor used. This insertion loss can be distributed within the wide limits between the transmit and receive cycles.

From the standpoint of the design of the varactor duplexer, it is best to place most of the insertion loss in the receive state. The insertion loss on the transmit cycle determines the power handling capability of the duplexer. The flat leakage energy that reaches the mixer diodes during transmitting is much less severe than the same ergs of spike leakage; therefore, the energy per pulse reaching the mixer diode may be safely higher than if a TR device is used.